



ENCLOSED ARE COPIES OF THE FOLLOWING:

IF MATERIAL IS NOT AS LISTED, PLEASE NOTIFY US AT ONCE

Hard copies for your file

MEMORANDUM

CH2M HILL

TO: Doug Liden/USEPA
(your reference: W-5-1)

COPIES: Sheila Wiegman/ASEPA
Pati Faiai/ASEPA
Norman Lovelace/USEPA
Norman Wei/StarKist Seafood
James Cox/Van Camp Seafood

FROM: Steve Costa/CH2M HILL

DATE: 12 November 1991

SUBJECT: Joint Cannery Outfall Mixing Zone Issues

PROJECT: PDX30702.PA.NP

PURPOSE

Included in USEPA's letter transmitting Limno-Tech's review of the Joint Cannery Outfall Zone of Mixing Application (Pago Pago Harbor, American Samoa) were questions on two additional issues.

- American Samoa Water Quality Standards (ASWQS) with respect to un-ionized ammonia in the zone of mixing
- Proposed mass limits based on zone of mixing analysis

The purpose of this memorandum is to respond to your concerns and questions regarding these items.

ASWQS and AMMONIA

Contrary to the interpretation expressed in the letter, ASWQS do not expressly state that toxic substances are not allowed within the mixing zone. Sections of the ASWQS quoted in the letter state:

- [1] Section 24.0208 (b) (5) says that "determination of effluent limits for toxic substances must comply with Section 24.0207 (a) (8) (A)-(E) and 24.0207 (a) (9);"
- [2] Section 24.0208 (b) (6) says that "standards set forth in 24.0207 (a) (1)-(4) shall be met within a zone of mixing;"

Our interpretation of the ASWQS is that limits for toxic substances should be determined per USEPA guidance based on dilution at the edge of the zone of mixing (ZOM) and the edge of the zone of initial dilution (ZID). Our interpretation is based on the following:

- Addressing the second point [2] above: 24.0207 (a) says "the following standards apply to all ... waters ... except as otherwise provided in Section 24.0208 (Zones of Mixing)."
- Section 24.0207 (a) (4) says: "[waters] shall be substantially free from substances and conditions ... which may be toxic ...". We interpret "substantially free" to imply that there are limits to toxic substances. Any other interpretation would lead to a situation that would virtually prohibit any discharge at all into any waters.
- The first point [1] above clearly states that limits for toxic substances are recognized in the mixing zone and those limits must comply with certain provisions.
- In particular Section 24.0207 (a) (8) (D) specifically states " ... effluent limits based on acute and/or chronic toxicity tests of effluents may be prescribed by EQC." Which again implies the establishment of limits.

The ASWQS provide for the acceptance of limits of toxic substances within the mixing zone. The criteria of the ASWQS therefore don't necessarily apply at the end of the pipe if a mixing zone is permitted. However, the standards do not address the method for determining limits.

It is expected that the limits should be determined based on USEPA guidance (Technical Support Document for Water Quality-based Toxics Control, EPA/505/2-90-001, 1991). The USEPA guidance generally allows the criteria maximum concentration (CMC) to be met at the edge of the ZID and the criteria continuous concentration (CCC) at the edge of the ZOM.

The CMC and CCC for un-ionized ammonia are provided in Attachment 1 to your letter. These values are given as 0.233 and 0.035 mg/l, respectively.

CRITERIA AT EDGE OF THE ZID

The regulatory ZID can be defined a number of ways and the most restrictive is then taken to apply. If the CMC cannot be met at the edge of the ZID then an alternative ZID may be defined. For the proposed diffuser the most restrictive definition is 50 times the discharge length scale which is, for a port diameter of 5 inches, 18.5 feet (5.6 meters). For maximum effluent discharge (worst case conditions) the dilution at a distance of 5.6 meters from the diffuser port is approximately 25 to 30 (see Appendix A of the Zone of Mixing Technical Memorandum, CH2M HILL, August 26, 1991).

The only ammonia value available for StarKist Samoa effluent, since implementation of high-strength waste segregation, is 78.5 mg/l, the maximum pH value for StarKist Samoa is 8.2. This value for pH was measured one time (September 8, 1990) during a 12 month period for a total of 45 minutes. Typical daily maximum pH values are 7.2 or less. Assuming a maximum temperature of 30 degrees C, the associated un-ionized ammonia value would be 8.87 mg/l. A dilution of 30 then gives a value of 0.296 mg/l at the edge of the most restrictive regulatory ZID boundary. This is compared to the CMC of 0.233 mg/l. Since the most restrictive of the regulatory ZID dimensions will not apply an alternative ZID should be determined.

The intent of defining a ZID boundary is to minimize exposure time of organisms to elevated concentrations. Typically the exposure time should be on the order of minutes. Using the results from the dilution models (zero current, maximum effluent flow case) exposure times of 30, 60, and 90 seconds correspond to dilutions of approximately 80, 170, and 275. These dilutions would result in concentrations of 0.111, 0.0522, and 0.0323 mg/l at distances of approximately 12, 20.5, and 28.5 meters from the diffuser, respectively.

The only ammonia value available for Samoa Packing effluent, since the implementation of high-strength waste segregation, is 57.8 mg/l, the maximum pH value for Samoa Packing is 9.1. However, seawater maximum pH in near surface waters is about 8.4, the highest observed in Pago Pago Harbor is about 8.2 to 8.3. The 9.1 value for Samoa Packing was only observed once and the next closest maximum was 8.4. Using a value of 8.4 and assuming a maximum temperature of 30 degrees C, the associated un-ionized ammonia value would be 9.71 mg/l. A dilution of 30 then gives a value of 0.323 mg/l at the edge of the most restrictive ZID boundary. This is compared to the CMC of 0.233 mg/l. The result is similar to the above calculations for StarKist Samoa effluent and an alternative ZID should be determined.

Following the same procedure as described above for StarKist Samoa, and using the results from the dilution models (at zero current, maximum effluent flow) for exposure times of 30, 60, and 90 seconds. Concentrations of 0.121, 0.0571, and 0.0353 mg/l at distances of approximately 12, 20.5, and 28.5 meters from the diffuser, respectively, are calculated.

For the worst case effluent flow and ambient conditions, the initial dilution process is over at a distance of about 33 meters corresponding to a dilution of approximately 350 and an exposure time of about 110 seconds. This is the edge of the physically defined ZID. The calculations above indicate that a regulatory ZID can be defined at or within the boundary of the physical ZID and meet the intent of minimizing exposure time of organisms.

CRITERIA AT EDGE OF THE ZOM

At the end of the initial dilution process the minimum dilution is approximately 350. The calculated un-ionized ammonia concentrations at this point are approximately, combining waste streams from both canneries, 0.025 mg/l. At the edge of the proposed mixing zone the minimum dilution is over 2000. The un-ionized ammonia concentration is calculated to

be about 0.0044 mg/l at the edge of the ZOM. This is compared to the CCC of 0.035 mg/l. The concentration at the edge of the physical ZID and throughout the rest of the mixing zone is lower than the CCC.

Typical background levels of un-ionized ammonia in surface sea water are expected to be in the range of 0.0005 to 0.005 mg/l at the temperature under consideration. For a rigorous analysis the values calculated above should account for the background values. Background or ambient harbor values are not known. However, considering typical marine values, it is obvious that the differences in results that would be obtained by accounting for background values will not significantly change the overall results.

SUMMARY

The ASWQS allow the determination of limits for substances such as un-ionized ammonia. Following USEPA guidelines the concentrations at the edge of the physical ZID and the edge of the ZOM appear to be consistent with national water quality criteria. There is no indication, based on available data, that any additional treatment is justified.

MASS LIMITS IN MIXING ZONE

The mass limits that are compatible with the mixing zone location and averages cover a range of possible conditions. The model predictions were done based on long term averages with superimposed maximum peaks. A low average loading permits a higher peak value than a high average. For example: the mixing zone analysis indicates that a monthly median loading of total nitrogen (TN) of 2000 pounds per day with a maximum of 4000 pounds per day is compatible with the proposed mixing zone. The analysis also indicates that a monthly median loading of total phosphorus (TP) of 400 pounds per day with a maximum of 800 pounds per day is compatible with the proposed mixing zone.

The averages presented in the discussion above assume that the daily loadings are continuous. If the canneries run on a weekly cycle with no, or small, loadings discharged on the weekends then the average loadings during production days are 2800 pounds per day of TN and 560 pounds per day of TP. The maximums of 4000 pounds per day of TN and 800 pounds per day of TP could occur for no more than 3 days consecutively.

Since the response time of Pago Pago Harbor is relatively slow (on the order of weeks), and the variability in TN and TP loadings from day to day is quite high (factor of >2 on production days), the best approach to mass loadings is to consider daily averages based on total monthly loadings with allowance for non-production days and peaks as described above. The example above would then translate to:

EXAMPLE COMBINED LIMIT FOR TOTAL NITROGEN

- Monthly (30 day) average of 2000 pounds/day which represents a total loading of 60000 pounds per month
- Daily average for production days not to exceed 2800 pounds per day
- Maximum loading in any one day not to exceed 4000 pounds for more than 3 consecutive days

EXAMPLE COMBINED LIMIT FOR TOTAL PHOSPHORUS

- Monthly (30 day) average of 400 pounds/day which represents a total loading of 12000 pounds per month
- Daily average for production days not to exceed 560 pounds per day
- Maximum loading in any one day not to exceed 800 pounds for more than 3 consecutive days

These values account for the present loadings and provide capacity for increased future loadings. The values are documented in Tables 2, 14, and 15 of the Zone of Mixing Technical Memorandum. Review of the information in the Technical memorandum indicates that these values provide a factor of safety superimposed on already conservative prediction techniques and assumptions.

The two canneries will each have individual NPDES permits and individual discharge limits will be established for each cannery as described in USEPA letters (June 20th, 1991) to each cannery which state:

"Based on USEPA's analysis of the data in each permit application, past Discharge Monitoring Reports (DMR's) and other appropriate data, USEPA will issue a separate NPDES permit to each cannery which will establish separate effluent discharge limits for each cannery at a point prior to the effluent's entry into the joint pipeline."

The loadings established for each cannery should involve a negotiated agreement between the canneries with concurrence of USEPA and ASG. However, an approved mixing zone should be substantially complete prior to the implementation of such an agreement. We should discuss the next steps in this process at our meeting on 13 November 1991.

MEMORANDUM

CH2M HILL

TO: Doug Liden/USEPA
(your reference: W-5-1)

COPIES: Sheila Wiegman/ASEPA
Pati Faiai/ASEPA
Norman Lovelace/USEPA
Norman Wei/Starkist Seafood
James Cox/Van Camp Seafood

FROM: Steve Costa/CH2M HILL

DATE: 10 November 1991

SUBJECT: Response to USEPA Comments on Zone of Mixing Application

PROJECT: PDX30702.PA.MZ

PURPOSE

The U.S. Environmental Protection Agency, through Limo-Tech, Inc., requested Dr. Steven J. Wright of the University of Michigan to review the Zone of Mixing Application for the Joint Cannery Outfall in Pago Pago Harbor, American Samoa. The purpose of this memorandum is to respond to Dr. Wright's comments, to clarify a few points on which Dr. Wright's comments were based, and to present our response to Limno-Tech's overall conclusions concerning the Zone of Mixing Application.

We have responded to Dr. Wright's comments point-by-point in the section indicated as "Response to Specific Comments" below. Following the section on specific responses we have addressed the overall conclusions presented by Limo-Tech in the "Response to General Comments" section. We then present our conclusions.

SUMMARY

We found Dr. Wright's review to be generally useful. However, there are some points concerning his interpretation of our analysis that require clarification. Because of some misinterpretation of our methods of analysis, Dr. Wright concluded that the attainment of water quality standards with the proposed zone of mixing and present loading conditions is marginal. He recommends additional analysis. We disagree with Dr. Wright's conclusions for the reasons described below.

RESPONSE TO SPECIFIC COMMENTS

A copy of Dr. Wright's review is attached (Attachment 1) and comments to which responses are provided in this memorandum are indicated in the margin of his review, and correspond to the numbering system below.

RESPONSES TO COMMENTS ON WASTEFIELD TRANSPORT MODEL

[1] As described in Chapter 2 of the Feasibility Study (CH2M HILL 1991a), the tidal and freshwater flows are very small. Most of the transport of water column constituents is driven by random and "quasi"-random processes. The most important of these is wind driven transport which is treated as a random process and represented as included in the eddy diffusion coefficient. Therefore, the major transport mechanism provided for by the model is gradient generated diffusive processes. The dispersion (or eddy diffusion) coefficients account for more than mixing processes on time scales that are small with respect to tidal periods.

Information presented in Chapter 2 also indicates that there are identifiable long term average currents (wind driven) in the harbor. Location of the diffuser in a favorable location will enhance the flushing and the use of a diffusion coefficient based on harbor-wide data will provide results that predict higher than expected concentrations (conservative predictions).

[2] The discharge from the Utulei Outfall was included in the model as a point source using the loadings described in the Waste Load Allocation Study (HRI 1989). All other point sources are small and are included in the nonpoint source inputs. We apologize for not making this point clearly in the model descriptions. Examples of input and output are provided in Appendix C of the Feasibility Study. We apologize for any confusion that might have arisen because the examples of I/O files are incorrectly described. On page C1-5 the last of items listed for the job control file are in error. The cells, flows, and loadings for point sources are not found in this file, but rather in the hydrodynamics and water quality/geometry files. In addition the input file examples are not necessarily consistent with the output file examples.

In the actual model runs the Utulei Outfall effluent was discharged to cell {I,J = 3,7} as shown on page C1-17. Total nitrogen (TN) loadings were taken as 59 kg/day and total phosphorous (TP) loadings as 27 kg/day. The effect of these loadings in this location is illustrated in Figure C3-16 and C3-32 for TN and TP, respectively. These figures represent the effect of the Utulei Outfall and all nonpoint sources (including small point sources). For an assumed oceanic background the TN is elevated above background by only a few percent.

[3] We agree that the use of a more sophisticated model is not indicated based on the available data. In addition the data requirements for a more complex model would be, because of the nature of the transport process and driving forces, extensive. However, it should be noted that the situation, as described below, results in conservative predictions

for discharge from the proposed diffuser site. The following points are important with respect to depth averaging:

- Past, and present, concentrations of nutrients in the harbor result from a surfacing plume
- The depths where concentrations were measured are surface, 70 feet (approximately) and bottom (HRI 1989)
- The primary density gradient is generally in the top 20 to 30 feet as described by the HRI data and the density gradient data used in the Feasibility Study (the system is approximated as a two layer system with a surface layer much thinner than the deep layer)
- An average of the three values (three depths) of nutrient concentrations will result in a depth average that is biased to the high side since there was no weighting factor applied and the highest (surface) values should have a relatively small weighting factor
- The diffusion constant based on calibration runs will therefore be smaller than it should be and the result will be a prediction based on artificially high depth averaged values reflecting apparently inhibited flushing of TN and TP from the harbor
- Future concentrations of nutrients will result from a generally trapped plume that will bias the depth averages less than for the case of a surfacing plume since the bottom layer occupies most of the water column

The model predictions for the outer harbor location are based on a model that underestimates flushing (low diffusion coefficient) and does not account for net current patterns as discussed in [1] above. The predicted depth averaged value is based on conservative approaches that would tend to predict high values. For the proposed diffuser location, the surface layer values of TN and TP will be somewhat lower than the depth average values predicted by the model.

RESPONSES TO COMMENTS ON INITIAL DILUTION MODEL

[4] UDKHDEN often predicts higher dilutions than other plume models in cases with currents, probably because the calculation of the curvature of the plume centerline tends to "delay" the attainment of surfacing or trapping (longer trajectories along the centerline). However, the situation is not straightforward. Figures 4-6 and 4-7 in the Feasibility Study present some model results for the outer harbor for three discharge depths and two discharge rates with all other variables held constant. These figures show the following:

- For zero current the dilutions predicted by the two models are consistent

- For zero current the predicted trapping depths are generally deeper (further below the surface) for UMERGE with the largest difference at the intermediate discharge depth (150 feet)
- For the 5 cm/sec case predicted dilutions are about the same for both models at a discharge depth of 100 feet
- For the 5 cm/sec case, at a discharge depth of 150 feet, dilutions predicted by UMERGE are about 60 percent of those predicted by UDKHDEN
- For the 5 cm/sec case predicted dilutions are about the same for both models at the high discharge rate but UMERGE predicts a dilution about 160 percent higher than UDKHDEN for the low discharge rate at a discharge depth of 200 feet
- For the 5 cm/sec case predicted trapping levels are somewhat higher for UDKHDEN at 100 feet, and somewhat higher for UMERGE at 150 feet
- For the 5 cm/sec case trapping level predictions, at a 200-foot discharge depth, are comparable for both models for the high flow rates but for the low discharge case UMERGE predicts a shallower depth (this is consistent with the higher dilution)

The differences in the models do not appear to be (solely) related to ambient current but rather more related to the ambient density and density gradients in combination with the ambient velocity (additional comparisons between the two models are provided in Appendix D of the Feasibility Study). Comparison of runs for the inner harbor conditions show good agreement between the models.

The final diffuser configuration is in about 180 feet of water and the effluent flow rates will vary considerably. Results from UDKHDEN appear to give more consistent results over a range of effluent discharge rates in terms of trends. At the higher effluent discharge rates and a 5 cm/sec ambient current UDKHDEN predicts the same or lower dilutions as UMERGE. It should also be noted that the 5 cm/sec ambient velocity is about two orders of magnitude lower than the discharge velocity through the ports. It is not a particularly rapid ambient current, and other factors are probably as important with respect to the differences in model predictions for the cases considered here.

Dr. Wright apparently did not run his modified UDKHDEN code for all of the same conditions we considered. For the cases he did run, his modified program appears to predict dilutions much lower than UMERGE for the 5 cm/sec case (approximately 1/3 of our unmodified UDKHDEN results). We feel this would be a unreasonably conservative prediction.

[5] All of the results used for the definition of the mixing zone are based on zero velocity. Therefore, as Dr. Wright points out, the choice of models is academic with respect to this point. However, our runs for non-zero velocities were done to get a feeling for the degree of conservatism in assuming a zero current situation. We consider a small current speed (about 5 cm/sec) to be a typically realistic condition. Our results, using either UDKHDEN or UMERGE indicate that the use of the zero velocity assumption is quite conservative compared to the more realistic 5 cm/sec assumption.

Based on UDKHDEN, and for conditions approximating the final diffuser location, the initial dilution at 5 cm/sec will be approximately 5 times the initial dilution at zero current (see tables in the Zone of Mixing Technical Memorandum, CH2M HILL, 1991b). Based on our experience comparing UDKHDEN with field data (dye studies), the model underestimates dilution at ambient velocities under 25 cm/sec and over 200 cm/sec. Between these extremes UDKHDEN has not appeared, in our experience, to overestimate dilution but has provided predictions fairly close to observations. Obviously, model and field data comparison is difficult and this is an area that needs more research. However, our professional judgement is to choose UDKHDEN, to assess the degree of conservatism, based on our experience and all of the factors discussed in [4] above.

If Dr. Wright's conclusion that UDKHDEN is predicting initial dilutions about 3 times too high at 5 cm/sec is accepted then our factor of conservatism is about 2 rather than 5. This, added to the known conservative predictions of any of the models at zero current, still results in a very conservative approach.

[6] The equation discussed by Dr. Wright relates the required dilution (S) to meet the water quality standard concentration (C_s) under conditions of ambient concentration (C_a) for a given effluent concentration (C_e) and is given by:

$$S (C_a - C_s) = (C_a - C_e).$$

Dr. Wright states that:

"There is a statement that C_a ought to be taken as the concentration outside the harbor, 0.12 mg/l for total nitrogen. However, this is the concentration of the water entrained into the plumes by definition and therefore must be the local concentration (at the location of the diffuser) predicted by the wastefield transport model or some similar approach.

He implies that we used the background value of 0.12 mg/l for TN and .0125 mg/l for TP as C_a in order to calculate the concentration at the end of initial dilution during the development of the mixing zone dimensions required. This is not the case and there appears to be some confusion or misinterpretation which we hope to clarify by considering the following points (underlines and bold added for emphasis):

- On page 4-12, Chapter 4 of the Feasibility Study Report we state:

"The closer the values of the standard and the ambient concentrations, the more difficult it is to meet the standards, that is the higher the initial dilution must be to meet the water quality standards. **For example, if** the ambient TN concentration is the ocean background **(the outfall is beyond the harbor entrance)** of 0.12 mg/l and the water quality standard is 0.200 mg/l, the required initial dilution to meet the standard,

This clearly refers to a hypothetical "best case" and it is clearly understood that such a condition ($C_a = 0.012$ mg/l) can only be attained outside the harbor.

- On the same page as above we further state:

"Moving the discharge **into the harbor where the ambient concentrations are higher** leads to even higher, and unattainable, initial dilution requirements.

This statement clearly demonstrates our recognition that 0.12 mg/l is not appropriate for use as C_a within the harbor.

- On page 4-13 of the Feasibility Study Report we state:

"For the middle and outer harbor ... the minimum initial dilution expected ... is over 150:1. For an effluent concentration of TN of 100 mg/l, the dilution at the end of initial dilution process is 0.87 mg/l **based on ambient concentration of 0.200 mg/l.**

If 0.12 mg/l had been used in the above equation for C_a the calculated concentration would have been 0.79 mg/l rather than 0.87 mg/l. This example actually represents a worst case scenario for initial dilution with the ambient concentration equal to the standard. We clearly recognized in our permit application and supporting documentation that the use of 0.12 mg/l as C_a is inappropriate inside the harbor.

- On pages 24 and 25 of the Zone of Mixing Technical Memorandum the first two points above are restated in the same manner. Please note that there are typographical errors in the equations on pages 24 and 25: on page 24, in the right hand term C_s should be C_a , and on page 25, in the left hand term 0.200 should be 0.120.

The points listed above were presented in a discussion of what initial dilutions would be required to meet the water quality standards accounting only for initial dilution. It must be

remembered that the S in the equation above is the required total dilution, which includes initial dilution, required to meet the standard under given conditions.

We obviously recognized in the zone of mixing application the points made by Dr. Wright concerning the need to use the ambient concentration at the location of the diffuser and that these values are derived from the long term waste loadings and the location of the diffuser. Dr. Wright apparently misread our description which we had simplified, maybe too much, for the discussion in the reports.

[7] As described above it was recognized in the zone of mixing application that it is inappropriate to use an ambient concentration equal to the background concentration at the diffuser location. The calculations summarized in Table 15 indicate that we recognize the need to use the local ambient concentration to calculate the required dilution to meet the standard. For example consider the first (left hand) column in Table 15A on Page 29 of the Mixing Zone Technical Memorandum:

- Effluent Concentration = 74.9 mg/l
- Ambient Concentration = 0.165 mg/l
- Standard Concentration = 0.200 mg/l
- Required dilution = $(0.165-74.9)/(0.165-0.200) = 2135$

The required total dilution to meet the standard is 2135. This is based on using the wastefield model predicted ambient concentration of 0.165 mg/l not the background concentration of 0.12 mg/l which would result in a required dilution of 934 (about half the actual required value, as pointed out by Dr. Wright).

In this case the available (model predicted) initial dilution was 395. This means that a subsequent dilution of 5.4 will be required to meet water quality standards under all of the assumptions used in the analysis, which are conservative.

Dr. Wright implies that the permit application is based on meeting the standards using initial dilution only. This implication is not the case. Again, the equation above refers to the total required dilution, only a part of which is accounted for by initial dilution. Some of the discussions presented by Dr. Wright concerning the possibility of meeting the standards with only initial dilution appear to have resulted from his misreading of the permit application and supporting documents. However, the information presented in our reports clearly indicate that meeting the standards using initial dilution only is not possible for the very reasons stated by Dr. Wright.

[8] For reasons described under our response to comment [3] above we do not think there is justification for lowering the model predicted ambient concentration as Dr. Wright suggested. This would reduce the predicted required mixing zone size. However, this

certainly would not be a conservative approach. With the diffuser in 170 to 180 feet of water and a trapped plume, the ambient concentrations at depth may actually be somewhat higher than the depth-averaged values. However, this is not of concern and would have only a small effect on the final calculations. Our approach was to, given a choice, use a somewhat higher value for ambient concentration than predicted.

RESPONSE TO COMMENTS ON FAR-FIELD TRANSPORT MODEL

[9] The model permits three options on length scale dependence: 0, 1, or $4/3$ power. The linear option (first power on length) was used for this case. This is a standard assumption for an semi-enclosed body of water with a nearby shoreline. A case for the "four thirds" power could be made since it is not intended to extend the calculations to a distance where the shoreline would have a major impact. However, given the proximity of shallow water on the reef we felt that the linear assumption was more appropriate. In any event, use of the "four-thirds law" would not substantially change the results.

[10] The use of this model does lead to conservative results for the reasons stated in the Technical Memorandum. In addition the entire approach of using a subsequent dilution model is more conservative than the general approach to mixing zone determination. In most studies farfield, nearfield, and initial dilution calculations are done. In this context a farfield calculation will be done to set average or steady state boundary conditions for the nearfield. This is analogous to our use of a constant background concentration at the entrance to the harbor. Then a nearfield model will be used to determine the ambient concentrations in the vicinity of the diffuser. This is essentially our application of the wastefield transport model (which can alternatively be thought of as serving as both farfield and nearfield models). Then initial dilution models will be used accounting for the ambient concentrations in the nearfield (as we did).

Usually the initial dilution model (accounting for ambient conditions) will be used to determine the zone of initial dilution (ZID) and the nearfield results will be used to determine the size of the zone of mixing. In both the feasibility study and the Zone of Mixing Technical Memorandum there is a discussion of the use of the wastefield transport model to estimate the required size of the zone of mixing. We decided to take the additional step and use a subsequent dilution model to account for the transition between the nearfield and the ZID and to provide a check on the use of the wastefield transport model. The subsequent dilution model effectively verifies the results concerning mixing zone size based on the wastefield transport model. The subsequent dilution model is a redundant check on the conclusions about required size of the mixing zone and that conclusion does not depend on the subsequent dilution model.

For the reasons stated in the text of the Technical Memorandum (page 26) we elected to apply a subsequent dilution model. The model is called a farfield dilution model to be consistent with the description in the documentation referenced. In the context of our application the term subsequent dilution is probably more appropriate since we do not extend the model results into what would be considered the farfield. The use of a subsequent dilution

model superimposed on a nearfield description is a conservative approach relative to typical mixing zone studies.

We have used the Brooks formulation routinely and are well aware of the implications and limitations of the model. We do not claim that lateral diffusion must balance horizontal advection as stated by Dr. Wright. We never make that statement. We recognize the limitations of the model at low velocities since there is no longitudinal diffusion term in the model. To simulate a zero current condition with this model we have set the current speed so that the longitudinal transport term (advective) is of the same size as the lateral transport term (diffusive). We did not use 5 cm/sec but rather 0.05 cm/sec as a current speed to simulate the zero current condition (see page 27 of the Technical Memorandum and page 4-13 of the feasibility study). Actually, a 5 cm/sec current would result in lower predicted dilutions at a given distance than the 0.05 cm/sec case. However, this would be adequately compensated for by the higher initial dilutions under such a condition.

[11] Dr. Wright brings up an interesting, and often overlooked point. We agree that mass conservation must be satisfied for realistic solutions. The subsequent dilution model is based on a mathematical singularity in the form of a "line source" of constant initial concentration and does not consider the effluent or constituent mass flow. To provide for physically realistic application the effluent flow rate must be equal to the flow of fluid past the source: as indicated in the comment, the flow through the source area must be sufficient to account for the effluent flow from the diffuser. This condition must also be met for the flux of any constituent. It is true that the subsequent dilution model does not meet this criteria in the neighborhood (in the mathematical sense) of the diffuser. However, the model does meet the criteria at a reasonable distance from the diffuser. We conclude that it is reasonable to use the model as formulated to verify the mixing zone dimensions required as shown by the following calculations:

CONDITION CLOSE TO THE DIFFUSER

- Consider an average effluent rate of 2.4 mgd which is equivalent to

$$2,400,000/7.5 = 320,000 \text{ cubic feet per day}$$

$$320,000/86,400 = 3.7 \text{ cfs}$$

- The initial mixing is by entrainment. The effluent flow is physically mixed with ambient water and the diluted waste stream or plume has a flow rate defined in terms of dilution (S). Consider an initial dilution of about 350, then the flow rate of the plume at the end of initial dilution is

$$(3.7 \text{ cfs}) \times (350) = 1295 \text{ cfs}$$

- The flow area through which this flow must pass under, the assumptions of the subsequent dilution model as it is formulated, is 200 feet wide. The depth is on the order of the distance between the trapping depth and the maximum rise depth of the plume, which is about 13 meters (this is close to the plume width, which is reasonable - see results in Appendix A of the Technical Memorandum)

$$200 \times 42.65 = 8,530 \text{ square feet}$$

- Therefore the velocity that the effluent plume must have across this area to maintain mass conservation is

$$1295/8,530 = 0.152 \text{ feet per second} = 4.6 \text{ cm/sec}$$

- The argument could be made that the effluent plume should be considered moving in both directions away from the diffuser (flow area 400 feet wide) or radially outward from the diffuser (flow area 634 feet wide). However, even with this adjustment the subsequent dilution model obviously is not applicable very close to the diffuser.

CONDITION AT A DISTANCE FROM THE DIFFUSER

- Consider the same average effluent rate of 2.4 mgd = 3.7 cfs
- The initial mixing is by entrainment. However, the subsequent dilution is by diffusion and the zero ambient current speed assumption is equivalent to assuming that the kinetic energy represented by the initial velocity of the effluent plume is dissipated in turbulent eddies in the receiving water. The conservation of mass still requires that, through any control volume around the diffuser, an outward flow of 3.7 cfs must be taking place.
- Under our formulation of a line source with a radial spreading front the flow area through which this flow must pass at the limit of the proposed mixing zone size is approximately 2,000 feet wide. The depth is on the order of the water depth which averages over 100 feet in the mixing zone area which results in a flow area of

$$2,000 \times 100 = 200,000 \text{ square feet}$$

- Therefore the velocity that the effluent plume must have to maintain mass conservation is

$$3.7/200,000 = 0.0000185 \text{ feet per second} = 0.00056 \text{ cm/sec}$$

- The argument could be made that the kinetic energy is not all dissipated very close to the diffuser. However, during many dye-dispersion field experiments our personal observations and measurements of surfacing plumes at times of slack water clearly indicate that the kinetic energy (velocity) in the plume dissipates rapidly. Our observations in the field indicate that the assumption of nearly total dissipation within a few plume diameters is reasonable. The subsequent dilution model obviously is applicable beginning a short distance from the diffuser.

Our use of 0.05 cm/sec to simulate zero current conditions appears physically reasonable, and does not violate mass conservation, for the characteristics of the system we are considering. If the extreme case were considered, and all kinetic energy was assumed dissipated immediately, then the current across the area at the line source would be 0.013 cm/sec. A current speed of 0.013 cm/sec in the subsequent dilution model (CDIFF) gives unrealistic results (an example run is given in Attachment 2). The basic problem with the model is not mass conservation but the difference in the transport mechanisms allowed in the longitudinal and lateral directions. It is not generally applicable at low speeds. We are purposely manipulating it to simulate a zero current condition. The approach is not rigorous but is a reasonable approximation. We would tend to agree that low current cases cannot be realistically modeled with the Brooks formulation. But, what we have done is a somewhat different application.

We do not completely follow Dr. Wright's reasoning for setting the ambient velocity at 5 cm/sec: we did not use 5 cm/sec, nor does an analysis of required current speeds indicate that 5 cm/sec is necessary (except very close to the diffuser). However the subsequent dilution model does appear to be applicable at this current speed. Attachment 2 to this memorandum provides examples of CDIFF runs at 5 cm/sec and for both the linear and 4/3-law assumptions.

The total flux of nitrogen or phosphorous and the total flow of water through any control volume around the diffuser must (assuming a conservative substance with no sinks) equal the mass discharging from the diffuser. Dr. Wright's mass balance equation considers advective transport only, which may be a good approximation only very close to the diffuser. The model, and the physical system, under consideration includes both advective and diffusive transport terms. We suspect a transcription or typographical error in the equation and believe that the right hand term, assuming S is taken to be dilution and C_s the water quality standard concentration, should be $SQ_e C_s$. However, we believe the right hand term is not an appropriate description of the problem if the water quality standard is not met by initial dilution, since there is no consideration of diffusive transport whatsoever.

[12] As stated above, we agree that low current cases cannot be realistically modeled with the Brooks formulation. What we did was a somewhat different application, and the technique is used to approximate a worst case condition, in what we believe is a conservative fashion.

[13] Again, we did not use 5 cm/sec as described above. If we did assume this was appropriate we would also use 5 cm/sec to calculate initial dilutions. On page 25 of the Technical Memorandum supporting the Zone of Mixing Application we do not state that near field dilutions of 875 to 1250 are required. We state that if the discharge is outside the harbor initial dilutions of 875 to 1250 would be required if the standard were to be achieved with initial dilution only. We further state that inside the harbor even higher dilutions are required. In Table 15 the required dilutions are presented for a variety of cases. The value suggested by Dr. Wright of 2000 (for TN) is actually lower, and less conservative, than our assessment of required dilutions as used in the analysis of mixing zone size.

[14] A subsequent dilution of 3-4 at 1300 feet for a current speed of 5 cm/sec appears reasonable. A model run for CDIFF at this current speed is provided in Attachment 2. We agree that this would require initial dilutions of 500 or more to meet water quality standards. Such dilutions are higher than predicted for trapped plumes at zero current speed. However, they are predicted for zero current speed at surfacing plume conditions (see Table 12, page 20 of the Mixing Zone Technical memorandum) and are predicted for a current speed of 5 cm/sec for the trapped plume (the above discussion of appropriate initial dilution models being considered, see for example Table 10 on page 17 of the Technical Memorandum). Please note that on Table 10 for the 2.0 mgd, 5 cm/sec case the dilutions, trapping levels, and plume widths are switched between lines 2 and 3 (4-inch, weak density gradient and 6-inch, strong density gradient). Therefore, the proposed mixing zone is consistent with both the zero current and the 5 cm/sec ambient current conditions.

Increases in future loading are adequately accounted for in our analysis as summarized in Table 15. This analysis was based entirely on a zero current speed assumption. The data presented indicates a current speed of, for example, 2.5 or 5 cm/sec applied to both initial and subsequent dilution would not change our conclusions as to mixing zone size and supportable loadings. We do not understand why an increase in loadings necessarily results in a decrease in initial dilution, as stated by Dr. Wright. Increased loadings may not result in comparable increased effluent rates. In addition, the diffuser has been designed with additional ports that will be blocked at installation but can be opened in the future if required. This design will accommodate increased effluent flows with no degradation in initial dilution. Table 15 in the Technical Memorandum indicates the potential for increased average and peak loading values to account for future growth.

[15] For the reasons stated above we strongly disagree that the attainment at the edge of the mixing zone is marginal, nor do we feel that any additional analysis is required for present or future loadings. We consider the analysis done to be conservative.

RESPONSE TO GENERAL COMMENTS

A copy of Limno-Tech's summary of Dr. Wright's review is attached (Attachment 1) and comments to which responses are provided in this memorandum are indicated in the margin of the summary, and correspond to the numbering system below.

[S1] The loading from the Utulei treatment plant were included as a point source in the model. All other sources were included in the nonpoint source terms. More detail is provided in the response to item [2] above.

[S2] UDKHDEN predictions under conditions of non-zero ambient currents are higher than the predictions of other EPA plume models. We do not think they are higher than expected conditions for relatively low speeds (like 5 cm/sec). However, the initial dilutions used to size the zone of mixing were based on zero current speed and the predictions agree well with UMERGE and Dr. Wright's modified UDKHDEN. This point is then academic unless it is desired to base the mixing zone size under the assumption of non-zero current speeds. Additional detail is provided in the responses to items [4] and [5] above.

[S3] Contrary to the comment the study does not assume that the ambient concentrations near the edge of the mixing zone are represented by concentrations outside the harbor. Actual (predicted) concentrations, which are higher than ocean background, are used and the determination of the required dilution does account for this effect. This conclusion is based on comments by Dr. Wright that are based on his misinterpretations of our procedure. This point is discussed in considerable detail in the responses to items [6], [7], [13], and others above.

[S4] We recognize that subsequent dilution (farfield) model is not appropriate for very low currents. However, it can be manipulated to simulate the condition of zero-current by appropriate choice of current speed. This approach is not standard but is formulated in a fashion that is consistent with the physics of the system. Our professional opinion is that the use of the model in refining the mixing zone dimensions, results in conservative predictions. More detail is provided in response to items [9], [10], [11], and [12] above.

[S5] Evidently the reviewers think that the proposed mixing zone size is considered "marginal" for present loadings. We disagree with the comment and believe it is based on misunderstandings and a cursory review of our analysis. There was no indication given by the reviewer of what additional "analysis of design criteria" is being referred to in his comments. The diffuser configuration has been optimized considering all factors. Movement of diffuser location will not substantially change the required mixing zone size. The only other alternatives involve lower loadings or larger mixing zones, neither of which we believe are necessary.

CONCLUSIONS

We appreciate the reviewers comments. However, we believe the conclusions of the reviewers were based on a review that was cursory in scope and effort. After addressing all of the comments the only issue is the use of CDIFF to simulate zero current conditions for subsequent dilution calculations for this system. We understand the reluctance about manipulating and using CDIFF in a somewhat unconventional fashion for this system (but not for the reasons stated). As described above the consideration of subsequent dilution

is not common in defining mixing zones and is usually not done. Given the environmental sensitivity of the nearby coral reefs we determined that the additional consideration was appropriate. During the analysis alternative ways of addressing the subsequent dilution problem were considered which were as follows:

- Do not consider subsequent dilution at all and simply use the wastefield transport model results to predict the required size of the mixing zone
- Do not consider subsequent dilution at all and use the wastefield transport model with a smaller grid size (about 200 feet) in the immediate vicinity of the diffuser with boundary conditions derived from the existing ("large grid") model results to predict the mixing zone size
- Use a more sophisticated model that provides a fully two dimensional (or three dimensional) description of the subsequent dilution due to eddy diffusion in all directions (CH2M HILL has developed a model, PT211, that will do such calculations)

We did not use and do not recommend any of these approaches. We believe, based on our experience and judgement that all of the alternative approaches would have resulted in a less conservative approach. In addition, the use of a smaller grid size or a more sophisticated model would be impossible to justify due to lack of field data for calibration. This would be a particularly severe problem for a model such as described in the last point above. The collection of such data is not feasible because of the amount (number of stations and variables) and length of time series (order of at least a few years) of data required.

It is our professional opinion that the analysis done supports the required zone of mixing location and size proposed in the permit application to American Samoa Environmental Quality Commission. It is also our professional judgement that the analysis was done in a conservative manner, addressing the protection of environmental resources and water quality with a reasonable and prudent factor of safety. We do not believe that any additional analysis is required.

REFERENCES

CH2M HILL. *Engineering and Environmental Feasibility Evaluation of Waste Disposal Alternatives*. Draft Final Report. Prepared for Starkist Samoa, Inc. February 1991a.

CH2M HILL. *Site-Specific Zone of Mixing Determination for the Joint Cannery Outfall Project: Pago Pago Harbor, American Samoa*. Technical Memorandum prepared for Starkist Samoa, Inc. and Samoa Packing Company. August 26, 1991b.

Hydro Resources International (HRI). *A Waste Load Allocation Study for Pago Pago Harbor, American Samoa*. Prepared for American Samoa Environmental Protection Agency. 1989.

October 25, 1991

Doug Liden
U.S. Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, CA 94105

U.S. EPA reference: W-5-1
Mixing Zone Application for Starkist Samoa

Review by :

Dr. Steven J. Wright *Stu J. Wright 10/25/91*
Department of Civil and Environmental Engineering
113 Engineering 1A
The University of Michigan
Ann Arbor, MI 48109-2125
Telephone (313-764-7148) Fax (313-763-2275)

Dear Mr. Liden:

Dave Dilks from Limno-Tech has passed on to me the information that you provided in the Mixing Zone application for Starkist Samoa and Samoa Packing Company for the proposed outfall in Pago Pago harbor, American Samoa. Following are my comments from my review of the documentation provided. In general I have no major difficulties of the analyses presented for the initial dilution or the wastefield transport modeling but I discuss some specific points below. However, I believe that there are some major problems with the application of the so-called "far-field" transport model and that these will have a major impact on the interpretation of the analysis. Again more specific details are provided below. If you should wish to speak personally with me about these issues, please feel free to contact me at my University telephone number (generally afternoons after 1:30 P.M. will be best) or my home telephone (313-475-1568 after about 6:00 P.M.

1 | Wastefield Transport Model - This model basically provides a long term simulation of the transport in the Pago Pago harbor accounting only for advection due to tidal motions and any fresh water inflows. The dispersion coefficients then relate to any mixing processes that occur on time scales that are small with

1 respect to a tidal period and were estimated by calibration of the model against
observed data. The magnitudes of the dispersion coefficients as well as the trend of
2 increasing dispersion in the outer harbor appear to be reasonable and the results
of this model are probably realistic. One major question that I have is with respect
to other inputs. In some of the provided figures, there is an outfall referred to as
the Utulei outfall which is a wastewater treatment plant discharge. I cannot tell if
3 the loadings from this outfall are significant or if they have been included in the
analysis; these issues should be clarified. In the writeup, there is a discussion
regarding nonpoint discharges and I do not know if this outfall discharge got
lumped into them or not. I do not have access to the HRI(1989) report and maybe
this issue is addressed in there. The second issue is that the analysis is using a
depth-integrated model. The comparison against field observations is facilitated by
averaging surface and at-depth water quality measurements, but the individual
data indicate some vertical stratification in water quality. However, the available
3 data are probably inadequate to justify the use of a more sophisticated approach
such as using only a portion of the water column as an effective depth in the model
and so I would not quarrel with the analysis but simply suggest that the actual
long term transport may have a depth variation that will result in differences for a
submerged waste field as compared to the existing waste discharges.

Initial Dilution Model - The USEPA models UMERGE and UDKHDEN were used
in the feasibility study with only the latter model used in the final analysis
presented in the Mixing Zone Application. In general, the application of these
models seems appropriate and the only issues that I would raise are with respect
to the interpretation of the results. There is some discrepancy between UMERGE
and UDKHDEN in the simulations with the 5 cm/s current and it is suggested that
since UDKHDEN is the more sophisticated model, it should be correct. I had
thought that it was fairly common knowledge that UDKHDEN predicts higher
dilutions in cases with currents than any of the other EPA plume models. In 1989,
I prepared a short report for Region II¹ that documented some problems with the
4 existing version of UDKHDEN (*Verification of EPA Plume Model UDKHDEN* by
S.J. Wright, September 80, 1989, 40 pp.) in a comparison of a fairly extensive set of
laboratory and field data and suggested some minor changes to the code that
would significantly improve the predictions. In running my modified code for
some of the same conditions as presented in the mixing zone application, I get
5 dilutions that are only about one-third those presented. Therefore, I would suggest

that the UMERGE results for cases with current are probably more accurate. Most of the results presented in the application are for the zero current case and
5 my model does not give significantly different results and since these are the results generally discussed in the application, I do not have much difficulty with the general conclusions.

There is a discussion of how to interpret the dilution that I believe is incorrect and this becomes more important in the discussion of the far field model below, so I will discuss this in detail here. In the feasibility study (and elsewhere), the average dilution is defined as

$$S = \frac{C_a - C_e}{C_a - C_s}$$

6 in which C_s is the concentration at the end of the initial dilution process, C_a is the ambient concentration, and C_e is the effluent concentration. There is a statement that C_a ought to be taken as the concentration outside the harbor, 0.12 mg/l for total nitrogen. However, this is the concentration of the water entrained into the plumes by definition and therefore must be the local concentration (at the location of the diffuser) predicted by the wastefield transport model or some other similar approach. In general, this depends upon the long term waste loadings as well as the position of the diffuser and therefore makes the determination of ZID concentrations more complicated. There are two factors however, that should be considered. First the ambient concentration will be higher than 0.12 mg/l (TN) and therefore the required initial dilution to meet the ambient water quality standards will be greater. For example if the local ambient concentration is 0.16
7 mg/l TN, then the required initial zone dilution would have to be twice as much as stated in the feasibility study and permit application in order to meet the receiving water standards. Although it is not proposed to meet these standards at the end of the ZID, this result still indicates that it will be more difficult to meet ambient
8 water quality standards elsewhere. The second factor is that most of the entrainment water is derived from depth, and this ambient water generally exhibits lower concentrations of TN and TP than the surface waters which make up the bulk of the water quality samples. This implies that a somewhat lower ambient concentration than obtained from the wastefield transport model would probably be justified.

9 Far-Field Transport Model - This model derives from a conceptual model presented by Brooks which allows for a scale dependent dispersion coefficient. I am assuming that the "four-thirds law" option is used in the analysis although I could not find an explicit statement to that effect. In any case, there are many statements about how conservative the model is and it is further evident that the users do not understand exactly what the implications of this model formulation is. They note that the horizontal advection must balance the lateral diffusion or else the model gives unrealistic results, therefore justifying their use of a 5 cm/s current. Actually, the problem derives from a mass consistency requirement. The total flux of nitrogen and phosphorus in the assumed flow past the diffuser must equal that arising from the diffuser itself as in

$$C W h U_a = Q_0 C_0 = S C_0$$

11 in which C is the initial concentration in the far field model, W is the initial width of the wastefield (presumably approximately equal to the diffuser length), h is the thickness of the wastefield and Q_0 is the total effluent discharge. If the current speed is too small, C will end up greater than C_0 , leading to the dilemma noted in the analysis. Making approximate calculations for the waste field thickness and concentration from the initial dilution results gives a result in which $C = C_0$ for $U_a = 5$ cm/s, thereby justifying its selection, but not for the reasons noted in the report.

12 There are data available from which an estimate of the wastefield thickness can be made, but this really begs the issue of whether the model formulation is a valid one since the ambient current is not tied to an physical occurrence, but instead is what is needed to make the model work; low current cases simply cannot be realistically modeled with this combination of models,

13 Assuming that the analysis of the far field dilution at a current speed near 5 cm/s is accepted, then I think there is a problem still. On p. 25 of the mixing zone application, it is stated that near field dilutions of between 875-1250 are required. Using a more accurate estimate of ambient concentration will result in a doubling or more of these required dilutions as discussed above, so presumably the required dilution is somewhere on the order of 2000 or more. The far field transport model will yield an incremental dilution of about 3-4 (at a distance of 1300 ft from the diffuser), depending upon the specific assumptions employed, based upon hand calculations that I made with the same general analytical procedure employed in the model. This then requires an initial dilution of at least 500, which cannot be

14 attained in the zero current scenario with the proposed diffuser. An increase in future loadings even more severely restrains the present design, because of an increase in the ambient concentration and a decrease in the initial dilution.

15 The key question therefore would appear to be whether or not the zero current case is a valid condition for the initial dilution, but this is a typical approach for defining worst case conditions. Even allowing for a current but with a more appropriate analysis (UMERGE or modified UDKHDEN) makes the attainment of the water quality criteria at the edge of the mixing zone marginal, so a more careful analysis of design criteria and especially a consideration of future expansion capacity (from the point of meeting water quality standards) should be made before the permit is accepted.



LTI – Limno-Tech, Inc.
Memorandum

TO: Doug Liden, U.S. EPA

DATE: 10/28/91

FROM: Dave Dilks

PROJECT: PAGO

cc: J. Parker, SAIC

SUBJECT: American Samoa Mixing Zone Review

Attached please find a signed review from Dr. Steven J. Wright (a nationally recognized expert in mixing analyses) regarding the American Samoa mixing zone study. The most significant aspects of the review are:

- S1 | ▪ The wastefield transport modeling was appropriate, although it was not clear from the information provided how loadings from the Uulei wastewater treatment plant outfall were considered in the analysis.
- S2 | ▪ The initial dilution modeling was, for the most part, appropriate. UDKHDEN dilution predictions for the 5 cm/s current simulations were too high. The majority of simulations deal with the zero current situations; these simulations appear appropriate.
- S3 | ▪ The study is non-conservative in assuming that ambient concentrations near the edge of the mixing zone are represented by concentrations outside of the harbor. Actual ambient concentrations will likely be higher, and the true amount of dilution lower, than that assumed in the study.
- S4 | ▪ The far-field transport model used is not appropriate for simulating cases of low current.
- S5 | ▪ Attainment of water quality standard appears marginal for present loading conditions. A more careful analysis of design criteria should be provided before future expansion capacity is provided.

Feel free to call Steve or me directly with any specific questions you may have.

***** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE *****
 ***** EPA REGION 10 *****
 ***** Current = 0.012 cm/sec {Linear Dependence *****

DECAY RATE = .00 DAYS**-1
 DIFFUSER WIDTH = 200. FEET
 OCEAN CURRENT = .0 FEET/SECOND
 DISTANCE TO SHORELINE = 2000. FEET
 EFFLUENT CONCENTRATION = 100.
 INITIAL DILUTION = 1.0

DISTANCE (FEET)	EST. CONCENTRATION		EST. DILUTION	
	C/L	S/L	C/L	S/L
20.	7.49	2.57	13.3	38.9
40.	4.45	4.83	22.5	20.7
60.	3.70	4.19	27.0	23.8
80.	3.16	3.46	31.7	28.9
100.	2.71	2.90	36.8	34.5
120.	2.36	2.48	42.4	40.4
140.	2.08	2.16	48.1	46.4
160.	1.85	1.91	54.0	52.5
180.	1.67	1.71	60.0	58.6
200.	1.51	1.54	66.0	64.8
220.	1.39	1.41	72.1	71.0
240.	1.28	1.29	78.3	77.2
260.	1.18	1.20	84.4	83.5
280.	1.10	1.11	90.6	89.7
300.	1.03	1.04	96.8	96.0
320.	.97	.98	103.0	102.2
340.	.92	.92	109.2	108.5
360.	.87	.87	115.5	114.8
380.	.82	.83	121.7	121.1
400.	.78	.79	128.0	127.4

```

***** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE *****
*****                               EPA REGION 10                *****
***** Current = 0.012 cm/sec      {Linear}                    *****

```

```

          DECAY RATE =          .00 DAYS**-1
        DIFFUSER WIDTH =        200. FEET
          OCEAN CURRENT =          .0 FEET/SECOND
    DISTANCE TO SHORELINE =      2000. FEET
    EFFLUENT CONCENTRATION =      100.
        INITIAL DILUTION =        1.0

```

DISTANCE (FEET)	EST. CONCENTRATION		EST. DILUTION	
	C/L	S/L	C/L	S/L
200.	1.51	1.54	66.0	64.8
400.	.78	.79	128.0	127.4
600.	.52	.53	190.8	190.3
800.	.39	.39	253.7	253.4
1000.	.32	.32	316.8	316.6
1200.	.26	.26	379.9	379.7
1400.	.23	.23	443.0	442.9
1600.	.20	.20	506.2	506.0
1800.	.18	.18	569.3	569.2
2000.	.16	.16	632.5	632.4
2200.	.14	.14	695.7	695.6
2400.	.13	.13	758.8	758.7
2600.	.12	.12	822.0	821.9
2800.	.11	.11	885.2	885.1
3000.	.11	.11	948.4	948.3
3200.	.10	.10	1011.5	1011.5
3400.	.09	.09	1074.7	1074.6
3600.	.09	.09	1137.9	1137.8
3800.	.08	.08	1201.1	1201.0
4000.	.08	.08	1264.3	1264.2

```

***** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE *****
*****                               EPA REGION 10                *****
***** Current = 5 cm/sec      {4/3 Law}                        *****

```

```

          DECAY RATE =          .00 DAYS**-1
        DIFFUSER WIDTH =        200. FEET
          OCEAN CURRENT =          .2 FEET/SECOND
    DISTANCE TO SHORELINE =      2000. FEET
    EFFLUENT CONCENTRATION =      100.
        INITIAL DILUTION =        1.0

```

DISTANCE (FEET)	EST. CONCENTRATION		EST. DILUTION	
	C/L	S/L	C/L	S/L
200.	89.88	.00	1.1	*****
400.	69.47	.00	1.4	*****
600.	54.60	.00	1.8	*****
800.	44.19	.00	2.3	*****
1000.	36.68	.00	2.7	*****
1200.	31.07	.00	3.2	*****
1400.	26.75	.00	3.7	*****
1600.	23.35	.00	4.3	*****
1800.	20.61	.00	4.9	*****
2000.	18.37	.00	5.4	*****
2200.	16.50	.01	6.1	15907.1
2400.	14.93	.03	6.7	3723.2
2600.	13.60	.08	7.4	1233.5
2800.	12.45	.19	8.0	526.2
3000.	11.46	.37	8.7	270.7
3200.	10.59	.62	9.4	160.4
3400.	9.82	.94	10.2	105.8
3600.	9.15	1.32	10.9	75.9
3800.	8.54	1.72	11.7	58.1
4000.	8.01	2.13	12.5	46.9

```

***** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE *****
*****                      EPA REGION 10                      *****
***** Current = 5 cm/sec      {Linear}                        *****

```

```

          DECAY RATE =          .00 DAYS**-1
        DIFFUSER WIDTH =        200. FEET
          OCEAN CURRENT =         .2 FEET/SECOND
    DISTANCE TO SHORELINE =      2000. FEET
    EFFLUENT CONCENTRATION =       100.
        INITIAL DILUTION =        1.0

```

DISTANCE (FEET)	EST. CONCENTRATION		EST. DILUTION	
	C/L	S/L	C/L	S/L
200.	91.16	.00	1.1	*****
400.	73.35	.00	1.4	*****
600.	60.26	.00	1.7	*****
800.	50.95	100.00	2.0	1.0
1000.	44.08	.00	2.3	*****
1200.	38.82	.00	2.6	*****
1400.	34.68	.00	2.9	*****
1600.	31.34	.00	3.2	*****
1800.	28.58	.00	3.5	*****
2000.	26.27	.00	3.8	*****
2200.	24.30	.00	4.1	*****
2400.	22.61	.00	4.4	*****
2600.	21.14	.00	4.7	*****
2800.	19.84	.00	5.0	*****
3000.	18.70	.00	5.3	*****
3200.	17.68	.00	5.7	52855.4
3400.	16.77	.00	6.0	20680.5
3600.	15.94	.01	6.3	9309.4
3800.	15.20	.02	6.6	4697.6
4000.	14.52	.04	6.9	2604.0